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(54) **IGNITION APPARATUS HAVING AN ELECTRICALLY FLOATING SHIELD**

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(52) **U.S. Cl.** **123/633**; 315/85; 123/634
(58) **Field of Search** 123/634, 633; 315/85

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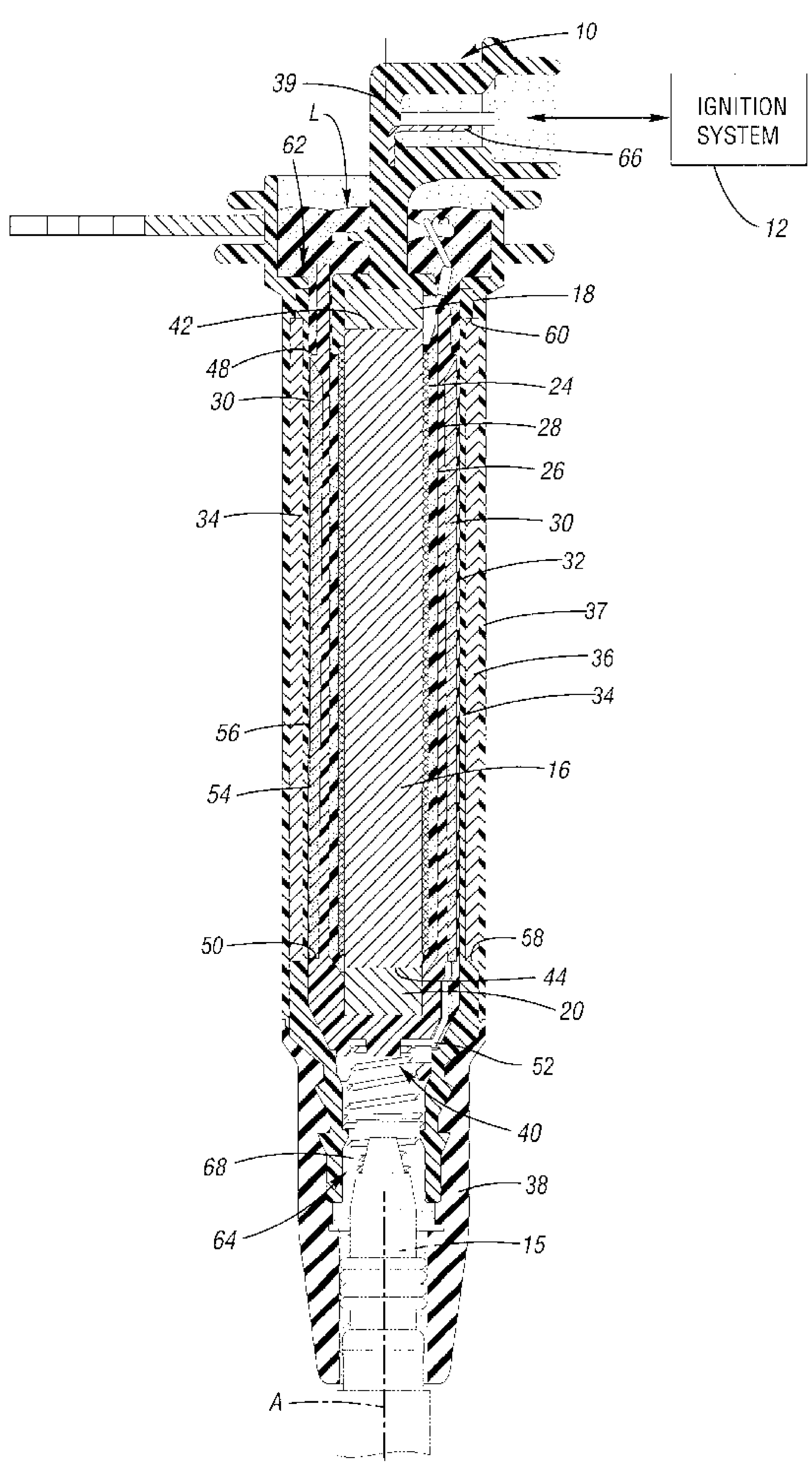
(57) **ABSTRACT**

An ignition apparatus includes a magnetic circuit comprising a central core and a side core or shield, and primary and secondary windings. The shield is allowed to electrically float, thereby reducing the capacitance of the secondary winding. A housing is external to and surrounds the shield to inhibit arcing. A silicone boot overlaps a housing/case interface to further suppress arcing.

18 Claims, 2 Drawing Sheets



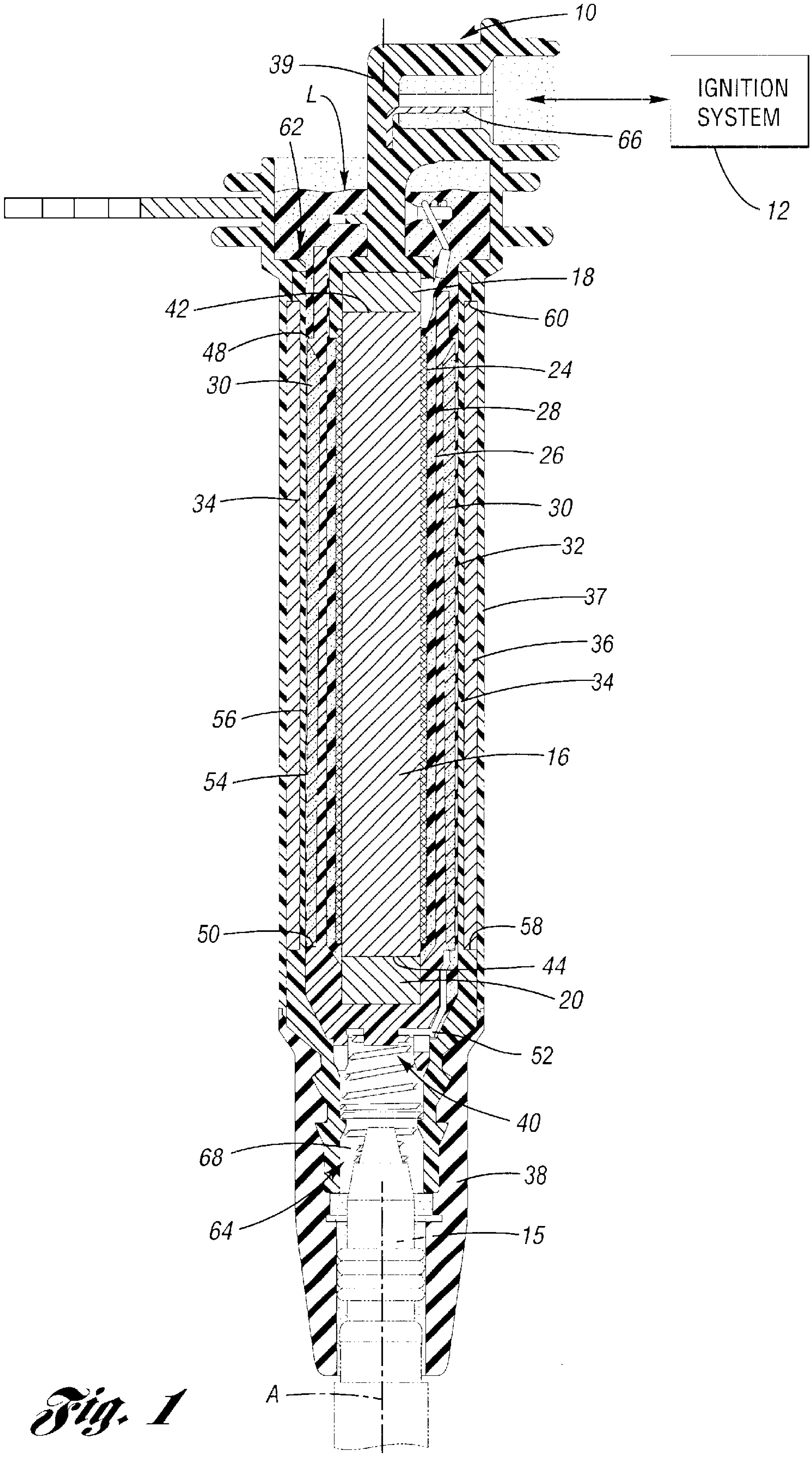

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Fig. 1

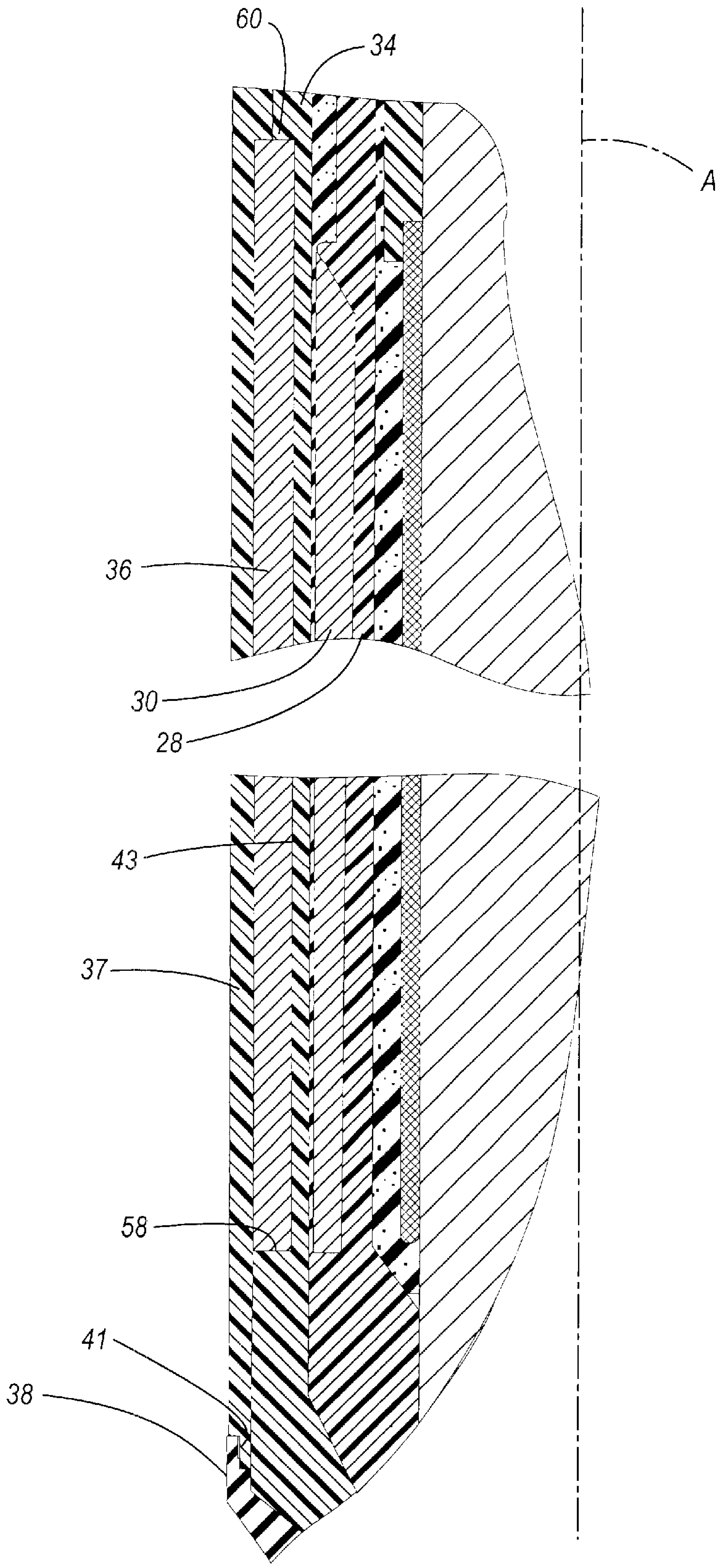

Fig. 2

IGNITION APPARATUS HAVING AN ELECTRICALLY FLOATING SHIELD

BACKGROUND OF THE INVENTION

1. Technical Field

The present invention relates generally to an ignition apparatus, and, more particularly, an ignition apparatus having an electrically floating shield.

2. Discussion of the Background Art

Ignition apparatuses utilize primary and secondary windings and a magnetic circuit. The magnetic circuit may include a central core formed of steel laminations or compression molded insulated iron particles, and a side core or shield, tubular in shape, formed of silicon steel, as seen by reference to U.S. Pat. No. 5,706,792 issued to Boyer et al. Boyer et al. further disclose an ignition apparatus having a relatively slender configuration adapted for mounting directly above a spark plug in a spark plug well—commonly referred to as a "pencil" coil. Boyer et al. further disclose that the shield is electrically grounded, ostensibly to inhibit a voltage rise from occurring at the shield. Boyer et al. further disclose that the shield is the radially outermost portion of the ignition coil (i.e., it has no electrical insulation outwardly thereof).

The ignition apparatus of Boyer et al. is of the type having a secondary winding that is outwardly of the primary winding. This type yields a relatively high electric field between the secondary winding and the shield. This electric field, among other things, results in a relatively high capacitance with respect to the secondary winding. The secondary winding voltage that can be obtained during operation is determined in terms of energy and capacitance, as follows:

$$V=\sqrt{2*E/C}$$

In order to obtain a short charge time and a low energy per pulse, for example as may be desirable in a multicharge/multistrike system, the low energy may not be able to charge the secondary winding capacitance to an acceptable value. This situation is generally undesirable.

There is therefore a need for an ignition apparatus that minimizes or eliminates one or more of the problems as set forth above.

SUMMARY OF THE INVENTION

An object of the present invention is to solve one or more of the problems set forth in the Background. One advantage of the present invention is that it provides an ignition apparatus having a secondary capacitance that is reduced relative to conventional ignition apparatuses, which allows a relatively short charge time. In addition, the reduced capacitance results in a reduced electric field between the secondary winding and the shield assembly (i.e., a reduced electric field through the case), thereby increasing durability of the ignition apparatus (i.e., a high electric field tends to break down common case materials due to corona discharge erosion).

An ignition apparatus according to the invention comprises a core having a main axis, a primary and secondary winding radially outwardly of the core, a first end of the primary winding being configured to be coupled to a power source and a second end coupled to ground, a conductive shield radially outwardly of the windings that is floating relative to ground, and a housing of electrically insulative material radially outwardly of the shield. Since the shield is allowed to float, the capacitance between the secondary winding and the shield drops by about four times. This reduces the overall capacitance seen by the secondary winding by between about 20% to 30% relative to conventional configurations where the shield is grounded. The shield, being ungrounded, however, rises to a voltage of about ½ the secondary voltage. During discharge (i.e., spark event) this level may be relatively high. The insulative housing inhibits arcing between the shield and a local ground (e.g., part of the spark plug well).

As an optional feature, the ignition apparatus further includes a boot, made of electrical insulative material, overlapping an interface where an axial end of the case engages the housing.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be described by way of example, with reference to the accompanying drawings, in which:

FIG. **1** is a simplified sectional view showing an ignition apparatus in accordance with the present invention; and

FIG. **2** is an enlarged sectional view showing an exemplary construction of a portion of the ignition apparatus shown in FIG. **1**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings wherein like reference numerals are used to identify identical components in the various views, FIG. **1** is an simplified sectional view of an ignition apparatus **10** in accordance with the invention, having an electrically floating side core or shield assembly. As is generally known, ignition apparatus **10** may be coupled to, for example, an ignition system **12**, which contains primary energization circuitry for controlling the charging and discharging of ignition apparatus **10**. Further, also as is well known, the relatively high voltage produced by ignition apparatus **10** is provided to spark plug **14** (shown in phantom-line format) for producing a spark across a spark gap thereof, which may be employed to initiate combustion in a combustion chamber of an engine. Ignition system **12** and spark plug **14** perform conventional functions well known to those of ordinary skill in the art.

Ignition apparatus **10** is adapted for installation to a conventional internal combustion engine onto a high-voltage terminal of spark plug **14**, which may be retained by a threaded engagement with a spark plug opening of an engine head.

Ignition apparatus **10** comprises in-effect a substantially slender high voltage transformer including substantially, coaxially arranged primary and secondary windings and a high permeability magnetic central core.

FIG. **1** further illustrates a central core **16**, an optional first magnet **18**, an optional second magnet **20**, a primary winding **24**, a first epoxy potting material layer **26**, a secondary winding spool **28**, a secondary winding **30**, a second epoxy potting material layer **32**, a case **34**, a shield assembly **36**, a housing assembly **37**, a boot assembly **38**, a low-voltage (LV) connector body **39**, and a high-voltage (HV) connector assembly **40**.

FIG. **2** illustrates in greater detail a portion of ignition apparatus **10** relating more particularly to the present invention. As described in the Background, the secondary voltage output of apparatus **10** is a function of the capacitance of the secondary winding according to a formula: $V=\sqrt{2*E/C}$.

According to the present invention, the capacitance of the secondary winding is decreased by not grounding shield assembly **36**, but rather by allowing shield assembly **36** to electrically "float" relative to ground. The shield assembly **36**, during the discharge of ignition apparatus **10** (i.e., via interruption of primary current, as known in the art), floats to about ½ the secondary voltage. The capacitance between the secondary winding **30** and shield assembly **36** drops by about four times, in accordance with the equation referred to above. A challenge, however, in allowing shield assembly **36** to float is that since it is at a relatively high voltage (e.g., ½ the secondary output voltage), there is a chance that the shield assembly **36** may arc to a nearby ground (e.g., spark plug well or other metal component of the engine in the vicinity).

According to the invention, an electrically-insulative housing **37** is disposed outwardly of shield assembly **36** to surround shield assembly **36**, thereby inhibiting an electric arc from occurring. To further reduce the chance of an arc occurring, boot assembly **38** is axially extended to overlap an interface where case **34** engages housing **37**.

In a preferred embodiment, the housing assembly **37** has a longitudinal extent greater than that of shield assembly **36**, to inhibit arcing through an interface boundary or region **41**. Also as shown, case **34** includes an annular groove **43** configured to receive shield assembly **36**. The groove **43** comprises first and second shoulders **58**, and **60**. Housing **37**, in the illustrated embodiment, overlaps shoulders **58**, **60**, again to reduce the chance of arcing.

Referring again to FIG. **1**, greater detail regarding the illustrated embodiment will now be set forth. Central core **16** may be elongated, having a main, longitudinal axis "A" associated therewith. Core **16** includes an upper, first end **42**, and a lower, second end **44**. For example, core **16** may be a conventional core known to those of ordinary skill in the art. Core **16** comprises magnetically permeable material, for example, a plurality of silicon steel laminations, or, insulated iron particles compression molded to a desired shape, as known. As illustrated, core **16**, in a preferred embodiment, takes a generally cylindrical shape (which is a generally circular shape in radial cross-section).

Optional magnets **18** and **20** may be included in ignition apparatus **10** as part of the magnetic circuit, and provide a magnetic bias for improved performance. The construction of magnets such as magnets **18** and **20**, as well as their use and effect on performance, is well understood by those of ordinary skill in the art. It should be understood that magnets **18** and **20** are optional in ignition apparatus **10**, and may be omitted, albeit with a reduced level of performance, which may be acceptable, depending on performance requirements.

Primary winding **24** may conventionally be wound directly onto central core **16** (e.g., when central core **16** is compression molded insulated iron particles), or may be wound on a primary winding spool (not shown) when core **16** comprises steel laminations. Primary winding **24** includes first and second ends and is configured to carry a primary current I_P for charging coil **10** upon control of ignition system **12**. Winding **24** may be implemented using known approaches and conventional materials.

Layers **26** and **32** comprise epoxy potting material. The potting material may be introduced into potting channels defined (i) between primary winding **24** and secondary winding spool **28**, and, (ii) between secondary winding **30** and case **34**. The potting channels are filled with potting material, in the illustrated embodiment, up to approximately the level designated "L". The potting material performs the function of electrical insulation and, provides protection from environmental factors which may be encountered during the service life of ignition apparatus **10**. There are a number of suitable epoxy potting materials well known to those of ordinary skill in the art.

Secondary winding spool **28** is configured to receive and retain secondary winding **30**. Spool **28** is disposed adjacent to and radially outwardly of the central components comprising core **16**, primary winding **24**, and epoxy potting layer **26**, and, preferably, is in coaxial relationship therewith. Spool **28** may comprise any one of a number of conventional spool configurations known to those of ordinary skill in the art. In the illustrated embodiment, spool **28** is configured to receive one continuous secondary winding (e.g., progressive winding), as is known. However, it should be understood that other configurations may be employed, such as, for example only, a configuration adapted for use with a segmented winding strategy (e.g., a spool of the type having a plurality of axially spaced ribs forming a plurality of channels therebetween for accepting windings).

The depth of the secondary winding in the illustrated embodiment decreases from the top of spool **28** (i.e., near the upper end **42** of core **16**), to the other end of spool **28** (i.e., near the lower end **44**) by way of a progressive gradual flare of the spool body. The result of the flare or taper is to increase the radial distance (i.e., taken with respect to axis "A") between primary winding **24** and secondary winding **30**, progressively, from the top to the bottom. As is known in the art, the voltage gradient in the axial direction, which increases toward the spark plug end (i.e., high voltage end) of the secondary winding, may require increased dielectric insulation between the secondary and primary windings, and, may be provided for by way of the progressively increased separation between the secondary and primary windings.

Spool **28** is formed generally of electrical insulating material having properties suitable for use in a relatively high temperature environment. For example, spool **28** may comprise plastic material such as polybutylene terephthalate (PBT) thermoplastic polyester. It should be understood that there are a variety of alternative materials which may be used for spool **28** known to those of ordinary skill in the ignition art, the foregoing being exemplary only and not limiting in nature.

Spool **28** may further include a first annular feature **48** and a second annular feature **50** formed at axially opposite ends thereof. Features **48**, and **50** may be configured so as to engage an inner surface of case **34** to locate, align, and center the spool **28** in the cavity of case **34**.

In addition, the body portion of spool **28** tapers on a lower end thereof to a reduced diameter, generally cylindrical outer surface sized to provide an interference fit with respect to a corresponding through-aperture at the lower end of case **34**. In addition, the spool body includes a blind bore or well at the spark plug end configured in size and shape to accommodate the size and shape of HV connector assembly **40**. In connection with this function, spool **28** may be formed having an electrically conductive (i.e., metal) high-voltage (HV) terminal **52** disposed therein configured to connect a high voltage lead of secondary winding **30** to the HV connector assembly **40**.

Secondary winding **30**, as described above, is wound on spool **28**, and includes a low voltage end and a high voltage end. The low voltage end may be connected to ground by way of a ground connection through LV connector body **39** in a manner known to those of ordinary skill in the art. The high voltage end is connected to the above-described (HV) terminal **52** for electrically connecting the high voltage generated by secondary winding **30** to HV connector assembly **40** for firing spark plug **14**. As known, an interruption of a primary current I_P through primary winding **24**, as controlled by ignition system **12**, is operative to produce a high voltage at the high voltage end of secondary winding **30**. Winding **30** may be implemented using conventional approaches and material known to those of ordinary skill in the art.

Case **34** may include an inner, generally cylindrical surface **54**, an outer surface **56**, a first annular shoulder or flange **58**, a flange **60**, an upper through-bore **62**, and a lower through bore **64**.

Inner surface **54** is configured in size to receive and retain the core **16**/primary winding **24**/spool **28**/secondary winding **30** assembly. The inner surface **54** of case **34** may be slightly spaced from spool **28**, particularly the annular spacing features **48**, **50** thereof (as shown), or may engage the spacing features **48**, **50**.

Annular shoulder or flange **58**, and flange **60** are located near the lower, and upper ends of case **34**, respectively.

Bore **62** is configured in size and shape to receive the combined assembly of core **16**/primary winding **24**/spool **28**/secondary winding **30**. Case **34** is formed of electrical insulating material, and may comprise conventional materials known to those of ordinary skill in the art (e.g., the PBT thermoplastic polyester material referred to above).

Shield assembly **36** is generally annular in shape and is disposed radially outwardly of case **34**, and, preferably, engages an outer surface **56** of case **34**. Shield **36** preferably comprises electrically conductive material, and more preferably, metal, such as silicon steel or other adequate magnetic material. Preferably the shield assembly **36** may include one or more cylindrical layers of silicon steel totaling a desired thickness. In one embodiment, the thickness may be between about 0.40 mm and 1.40 mm. Shield assembly **36**, among other things, provides a magnetic path for the magnetic circuit portion of apparatus **10**. As described above, shield assembly **36**, although electrically conductive, is not grounded but rather is allowed to electrically float.

Housing assembly **37** may be formed of the same or similar material as case **34** (e.g., PBT in one embodiment). The thickness of housing **37** is generally selected to provide adequate electrical insulation and adequate during both criteria of which depend, in part, on the material chosen. In one exemplary embodiment, when PBT is used, the housing assembly thickness may range between about 0.50–1.50 mm.

Boot assembly **38** may comprise silicone material or other compliant, electrically insulative material, as known in the art. As shown, boot assembly **38** may be configured to slightly overlap a lower annular shoulder of housing assembly **37**.

Low voltage connector body **39** is configured to, among other things, electrically connect the first and second ends of primary winding **24** to an energization source, such as the energization circuitry included in ignition system **12**. Connector body **39** is generally formed of electrical insulating material, but also includes a plurality of electrically conductive terminals **66** (e.g., pins for ground, primary winding leads, etc.). Terminals **66** are coupled electrically, internally through connector body **39**, in a manner known to those of ordinary skill in the art, and are thereafter connected to various parts of apparatus **10**, also in a manner generally know to those of ordinary skill in the art. Ignition system **12** may then control energization of primary winding **24**.

HV connector assembly **40** may include a spring contact **68** or the like, which is electrically coupled to HV terminal **52** (which is in turn coupled to the high voltage lead of secondary winding **30**) disposed in a blind bore portion formed in a lowermost end of spool **28**. Contact spring **68** is configured to engage a high-voltage connector terminal of spark plug **14**. This arrangement for coupling the high voltage developed by secondary winding **30** to plug **14** is exemplary only; a number of alternative connector arrangements, particularly spring-biased arrangements, are known in the art.

An ignition apparatus according to the present invention allows the shield to electrically float, thereby reducing the capacitance of the secondary winding. This permits a relatively short charge time, low energy pulse to be generated by the ignition apparatus. In addition, the electric field that is produced in the area or region between the shield and the secondary winding (i.e., through the case) is reduced. This increases the durability of the apparatus (i.e., punch through the case due to corona erosion of case material is reduced). Also, no connection of the shield to a ground terminal is required, reducing complexity and cost. In addition, shield coating requirements are reduced. Moreover, lowering the electric field across the case to allows the use of thinner case walls, which savings in thickness may be allocated to the thickness of the housing (i.e., no significant, if any, increase in overall radial size of the apparatus).

It is to be understood that the above description is merely exemplary rather than limiting in nature, the invention being limited only by the appended claims. Various modifications and changes may be made thereto by one of ordinary skill in the art which embody the principles of the invention and fall within the spirit and scope thereof.

What is claimed is:

1. An ignition apparatus comprising:

a cylindrical central core having a main axis;

a primary and secondary winding radially outwardly of said central core, a first end of said primary winding being configured to be coupled to a power source and a second end of said primary winding being configured to be selectively coupled to ground;

an annular magnetically-permeable conductive shield defining a side core radially outwardly of said windings that is floating relative to ground configured to provide a magnetic path; and

a housing of electrically insulative material radially outwardly of said shield.

2. The apparatus of claim **1** wherein said housing substantially surrounds said shield.

3. The apparatus of claim **2** wherein said housing has a longitudinal extent greater than that of said shield.

4. The apparatus of claim **1** wherein said housing is configured in size and shape to inhibit electrical arcing between said shield and ground.

5. The apparatus of claim **1** further comprising a case of electrical insulating material intermediate said windings and said shield.

6. The apparatus of claim **5** wherein said case comprises a groove configured to receive said shield.

7. An ignition apparatus comprising:

a core having a main axis;

a primary and secondary winding radially outwardly of said core, a first end of said primary winding being configured to be coupled to a power source and a second end of said primary winding being configured to be selectively coupled to ground;

a conductive shield radially outwardly of said windings that is floating relative to ground;

a housing of electrically insulative material radially outwardly of said shield;

a case of electrical insulating material intermediate said windings and said shield;

wherein said case comprises a groove configured to receive said shield; and

wherein said groove comprises first and second annular shoulders, said housing overlapping at least one of said shoulders.

8. The apparatus of claim **7** wherein said housing overlaps said first and second shoulders.

9. An ignition apparatus comprising:

a core having a main axis;

a primary and secondary winding radially outwardly of said core, a first end of said primary winding being configured to be coupled to a power source and a second end of said primary winding being configured to be selectively coupled to ground;

a conductive shield radially outwardly of said windings that is floating relative to ground;

a housing of electrically insulative material radially outwardly of said shield,

a case of electrical insulating material intermediate said windings and said shield; and

a boot overlapping an axial end of said case.

10. An ignition apparatus for an internal combustion engine comprising:

a cylindrical central core having a main axis formed of magnetically-permeable material;

a primary and secondary winding radially outwardly of said central core, a first end of said primary winding being configured to be coupled to a positive bus of a power supply and a second end of said primary winding being configured for selective connection to ground;

a case of electrical insulating material radially outwardly of said windings;

an annular magnetically-permeable shield defining a side core radially outwardly of said case wherein said shield is floating relative to said positive bus and said ground and is configured to provide a magnetic path; and

a housing of electrical insulating material radially outwardly of said shield.

11. An ignition apparatus for an internal combustion engine comprising:

a core having a main axis formed of magnetically-permeable material;

a primary and secondary winding radially outwardly of said core, a first end of said primary winding being configured to be coupled to a positive bus of a power supply and a second end of said primary winding being configured for selective connection to ground;

a case of electrical insulating material radially outwardly of said windings;

a magnetically-permeable shield radially outwardly of said case wherein said shield is floating relative to said positive bus and said ground; and

a housing of electrical insulating material radially outwardly of said shield, wherein said case comprises a groove have first and second shoulders, and configured to receive said shield.

12. The apparatus of claim **11** wherein said housing overlaps at least one of said first and second shoulders.

13. The apparatus of claim **12** wherein said housing overlaps said first and second shoulders.

14. The apparatus of claim **13** further comprising a boot of electrical insulating material overlapping said case.

15. The apparatus of claim **14** wherein said boot overlaps an axial end of said case.

16. A method of operating an ignition apparatus having charge and discharge intervals comprising the step of electrically floating an annular magnetically-permeable shield portion of the apparatus defining a side core and which is configured to provide a magnetic path.

17. The method of claim **16** further comprising the step of connecting an end of a primary winding to ground to generate a primary current.

18. The method of claim **17** further comprising the step of interrupting the primary current to thereby generate a spark voltage on an end of a secondary winding.

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